Update on the hadron spectrum with two flavors of staggered quarks

Claude Bernard,[a] Tom Blum, [b] Thomas A. DeGrand, [c] Carleton DeTar, [d] Steven Gottlieb, [e] Urs M. Heller, [f] Jim Hetrick, [a] * Craig McNeile, [c] Kari Rummukainen, [g] Robert Sugar [h] † and Doug Toussaint [i]

[a]Department of Physics, Washington University, St. Louis, MO 63130, USA

[b]Department of Physics, Brookhaven National Lab, Upton, NY 11973, USA

[c]Physics Department, University of Colorado, Boulder, CO 80309, USA

[d]Physics Department, University of Utah, Salt Lake City, UT 84112, USA

[e]Department of Physics, Indiana University, Bloomington, IN 47405, USA

[f]SCRI, Florida State University, Tallahassee, FL 32306-4130, USA

[g]Universität Bielefeld, Fakultät für Physik, Postfach 100131, D-33501 Bielefeld, Germany

[h]Department of Physics, University of California, Santa Barbara, CA 93106, USA

[i]Department of Physics, University of Arizona, Tucson, AZ 85721, USA

We present an update on the MILC Collaboration's light hadron spectrum calculation with two flavors of dynamical, staggered quarks. Results are presented for gauge couplings 5.30, 5.415, 5.50 and 5.60, with a range of quark masses for each value of the coupling. We present extrapolations of m_N/m_ρ to the continuum limit for fixed values of m_π/m_ρ including the physical one.

Over the past few years the MILC Collaboration has been engaged in a series of spectrum calculations with dynamical quarks and in the quenched approximation, using both standard and improved actions[1]. One objective of this work is to obtain sufficient control over systematic errors so that one can make reliable extrapolations to the limits of zero lattice spacing and physical quark masses. Another objective is to make detailed comparisons between the spectra with quenched and dynamical quarks, and with standard and improved actions. Clearly, to reach these objectives requires high statistics calculations for a sufficiently wide range of lattice spacings and quark masses to enable us to make extrapolations to the continuum and chiral limits. It also requires that these calculations be carried out on large enough lattices to avoid finite size effects.

In this note we provide an update on our results for two flavors of dynamical, staggered quarks using the standard gauge and quark actions. Results for the quenched approximation and with improved actions are presented elsewhere in these proceedings[2]. We have carried out simulations at four values of the gauge coupling, $6/g^2 = 5.30$, 5.415, 5.50 and 5.60 using at least four values of the quark mass at each coupling. Lattices were generated with the refreshed hybrid molecular dynamics algorithm. Once the lattices were equilibrated the light hadron spectrum was measured every fifth molecular dynamics time unit. Lattices were saved after every tenth time unit for use in other projects. With the exeption of a few runs at large quark mass, measurements were made on

*Current address, Department of Physics, University of the Pacific, Stockton, CA 95211, USA
†presented by Robert Sugar

at least four hundred lattices at each values of the gauge couping and quark mass.

As one would expect, the hadron masses evaluated in lattice units are strongly dependent on the gauge coupling and bare lattice quark mass, am_q. Here a is the lattice spacing. The one exception is the mass of the Goldstone pion which is weakly dependent on the gauge coupling. In Fig. 1, we plot the ρ mass as a function of the bare quark mass for the two weakest values of the gauge coupling that we have studied. For comparison we also include in this figure results from quenched calculations with staggered quarks at gauge couplings 5.70, 5.85 and 6.15. Notice that for fixed values of the gauge coupling, am_ρ decreases more rapidly for decreasing am_q in full QCD than in the quenched approximation. This is due to the dependence of the lattice spacing on the quark mass in full QCD.

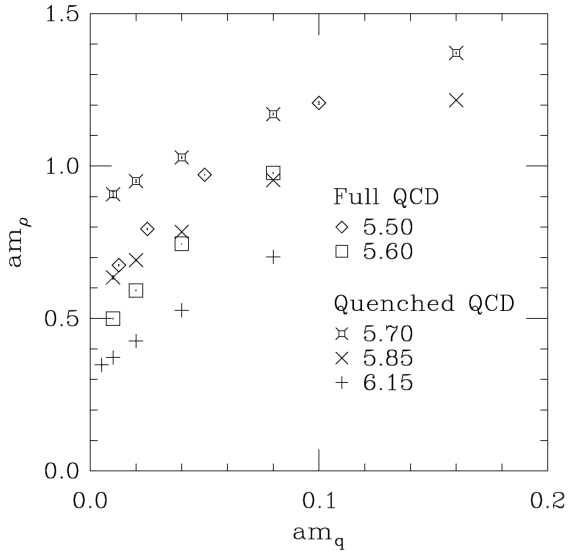

Figure 1. The ρ mass as a function of the quark mass for full and quenched QCD.

An important question regarding any simulation with staggered quarks is the extent to which flavor symmetry is restored as the lattice spacing and quark mass are decreased. One measure of flavor symmetry violation is the quantity $\delta_\pi = (m^2_{\pi_2} - m^2_\pi)/m^2_\rho$. In Fig. 2, we plot δ_π as a function of am_q for each of the couplings we

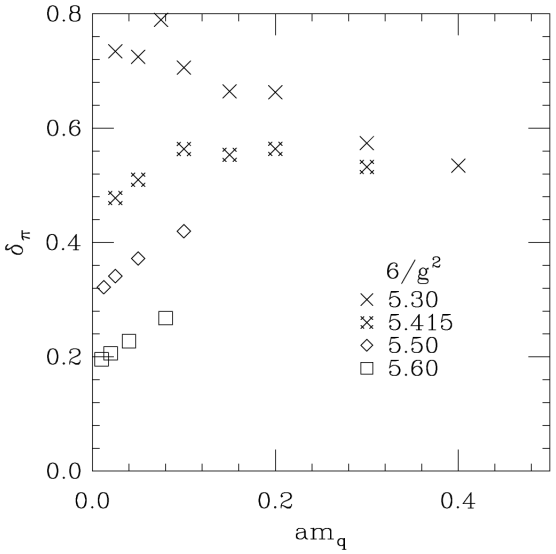

Figure 2. δ_π as a function of am_q for full QCD.

have studied. The trends are as expected. The value of δ_π for $6/g^2 = 5.60$ is close to, but slightly below that found in the quenched approximation for gauge coupling 5.85.

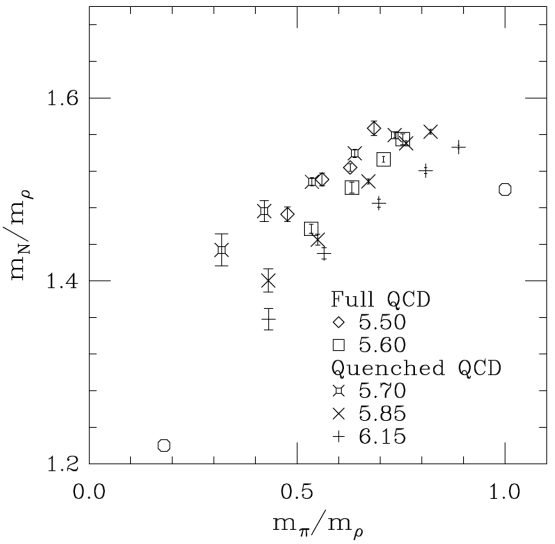

Figure 3. The Edinburgh plot for full and quenched QCD.

In Fig. 3, we show the Edinburgh plot for our two weakest gauge couplings using the Goldstone pion in the ratio m_π/m_ρ. Once again we include quenched results for gauge couplings 5.70, 5.85

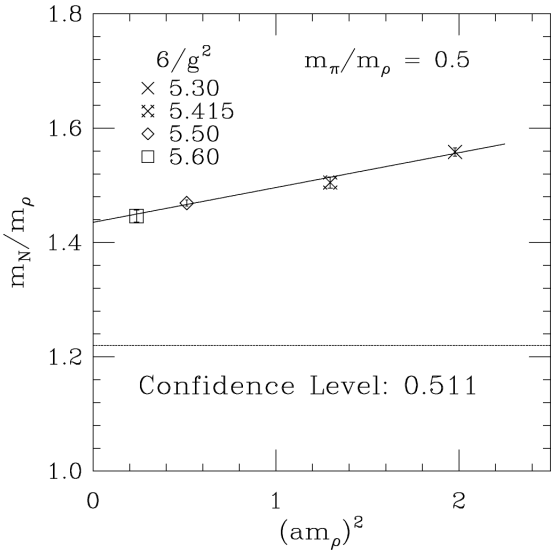

Figure 4. m_N/m_ρ as a function of the square of the lattice spacing for $m_\pi/m_\rho = 0.5$

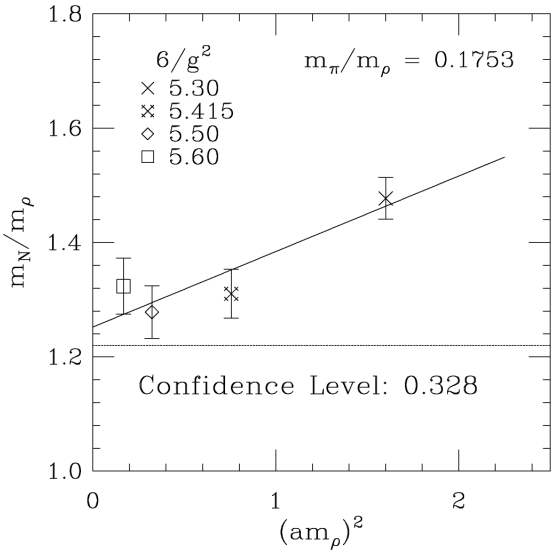

Figure 5. m_N/m_ρ as a function of the square of the lattice spacing with m_π/m_ρ fixed at its experimental value.

and 6.15 in this graph. Here too, the full QCD results at 5.60 are quite close to the quenched ones at 5.85.

Because we have carried out calculations with a number of quark masses at each value of the coupling we have studied, we can perform fits to the hadron masses as a function of am_q in order to extrapolate to the chiral limit and to interpolate for comparisons with quenched and improved action calculations. We are analyzing a variety of fitting functions. Here we present results from fits of the nucleon and rho masses to the form

$$m = m_0 + \alpha m_q + \beta m_q^{3/2} + \gamma m_q^2.$$

In Fig. 4 we show m_N/m_ρ for the four values of the gauge coupling we have studied, in each case interpolating to the value of am_q for which $m_\pi/m_\rho = 0.5$. The x-axis in this figure is $(am_\rho)^2$ interpolated to the same value of the quark mass. This quantity gives a measure of the square of the lattice spacing.

Fig. 5 is a repeat of Fig. 4, this time with extrapolations to the value of the quark mass for which m_π/m_ρ takes on its experimental value, 0.1753. The errors for the individual points in Figs. 4 and 5 were determined by a jackknife analysis. The solid lines in these figures are fits to the four interpolated or extrapolated points of the form $\alpha + \beta(am_\rho)^2$, where α and β are fit parameters. The confidence levels of these fits are shown in the figures. The fits allow an extrapolation of m_N/m_ρ to the continuum limit for fixed values of m_π/m_ρ, and they provide support of the expectation that for staggered quarks the leading corrections are of order a^2. These results are quite encouraging; however, a better understanding of the chiral extrapolation, as well as additional calculations at weaker coupling and smaller quark masses are needed in order to obtain definitive results.

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REFERENCES

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2. The MILC Collaboration, C. Bernard *et al.*, these proceedings.